perfSONAR for testing network configuration parameters

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Agenda

A slightly different use case for perfSONAR

- Normally perfSONAR is used for day-to-day network monitoring
- But it can also help us evaluate the effect of different network tuning parameters and to try emerging options such as TCP-BBR

- Topics…
  - The importance of network tuning
  - Leveraging *pscheduler* as a test harness
  - Jisc perfSONAR nodes
  - Some examples
  - Thoughts – what might we do to better support this use case?

The importance of network tuning

Why tune?

What's the rationale?

- Default operating system network tuning configurations are set for common application use cases
- Most use cases don't need any special configuration

- In R&E networks, we often have quite demanding applications, particularly around data-intensive science and very large data transfers
  - e.g., 10TB in an hour needs about 20Gbps
    or 1PB in 1 day needs around 100Gbps

- For happy researchers we need to optimise our use of available capacity

What might we tune?

What properties might we change to optimise throughput?

- Examples:
  - TCP Congestion control algorithm (CCA)
  - Maximum Transmission Unit (MTU) (packet size)
  - TCP window size (buffers)
  - Number of streams used by an application
  - Pacing (maximum throughput per stream)
  - Queueing algorithm
  - …

- There's a lot of great information on tuning at https://fasterdata.es.net/
  for various host OSes and network devices

Congestion control example - BBRv3

Bottleneck Bandwidth and Round-trip (BBR)

- BBRv3 was announced at the July 2023 IETF meeting
  - See https://datatracker.ietf.org/meeting/117/materials/slides-117-ccwg-bbrv3-algorithm-bug-fixes-and-public-internet-deployment-00 (an update from Google, who created the first versions and use it in production)
- Key innovation is not relying on packet loss to detect congestion
  - BBR measures throughput and latency to determine its send rate
- Open source, available on github:
  - https://github.com/google/bbr/blob/v3/README.md
- Holds a lot of potential benefit for large-scale R&E data transfers
  - Resilient to loss, adapts well to long distance scenarios (long fat pipes!)
- Not (yet) in production Linux distributions, but it should be evaluated

MTU - jumbo frames

Using large MTU packets

- The default MTU for ethernet LANs is 1500
- Using 9000 MTU can give improved throughput
  - Faster TCP ramp-up, fewer packets per second to process
  - See https://network.switch.ch/pub/tools/tcp-throughput/
- There was a WLCG proposal in 2018 to use jumbo frames:
  - https://indico.cern.ch/event/725706/contributions/3120030/attachments/1743507/2821722/LHCONE-MTU-recommendation.pdf
- Many WLCG sites do now run 9000 MTU, but many do not
- It would be very useful to measure the performance benefit of 9000 vs 1500 MTU, or other MTU values

TCP window size

How much data can be in flight?

- When TCP is used, its sending rate is limited by how much data can be in flight, before acknowledgements are received
- The “Bandwidth-delay product”
- For greater capacity paths, and higher round-trip time paths, the BDP will be greater
- Again, see https://network.switch.ch/pub/tools/tcp-throughput

- It’s useful to be able to test (Linux) window settings
- Though modern Linuxes do have some auto-tune support
- As you might guess, FasterData is a good source of information

Number of parallel streams

An application-oriented parameter

- If an application uses one TCP stream, its throughput will be determined by the performance of that stream
- By running multiple concurrent streams, the impact of one stream experiencing poor throughput (typically through packet loss with traditional TCP) is reduced
- Globus and its GridFTP tool use 4 streams by default
- It’s useful to be able to test the effect on overall throughput from running 1, 2, 4, or more concurrent streams

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Packet pacing

Controlling traffic sending rates

- A relatively new topic in the WLCG's Research Networking Technical Working Group (RNTWG)
  - Held a kick off meeting in May 2023
  - https://indico.cern.ch/event/1287745/sessions/494231/#20230525
- Pacing has potential to reduce traffic microbursts to improve overall throughput
- Particularly useful where shallow buffer devices are in use
- In principle there should be less buffering and thus fewer drops
- "Competing" streams can also be fairer to each other
- This can be tested by rate-limiting TCP streams

- Note that BBRv3 effectively paces itself, so will be interesting to compare

Leveraging *pscheduler* as a test harness

How can we use pscheduler?

Running comparisons

- You can of course run tests from your own perfSONAR server
- But a key feature of *pscheduler* is that it can also **run third party tests between two remote perfSONAR measurement points**
  - Requires those servers to be open for remote tests
- Tests can be run on demand or scheduled via pSConfig or other means
- If we want to make comparisons we could either
  - Re-tune the perfSONAR server and continue to run tests as normal, giving “before and after” measurements, perhaps for a day or a week
  - Use *pscheduler* to vary the server tuning on a per-test basis, which may give a better comparison given the network load is more likely to be similar
- Then the results and differences can be viewed or analysed

What parameters does *pscheduler* support?

Examples for throughput tests

- CCA: --congestion
- MTU: --mss (actually the TCP maximum segment size)
- TCP window size: --window-size
- Number of streams: --parallel
- Pacing: --bandwidth

- You can use any combination of the above
- See https://docs.perfsonar.net/pscheduler_ref_tests_tools.html

What else might we study?

Examples

- IPv6
  - Relative performance to IPv4
  - PMTUD operation, flow label transparency, …
- MTU limitations
  - Are there MTU misconfigurations?
  - We could detect MTU changes on a path using a *tracepath* test
- Explicit Congestion Notification (ECN)
  - Test with and without ECN enabled; is throughput improved?
  - BBR can leverage ECN

Jisc perfSONAR nodes

Jisc and network performance

Some Jisc resources

- Janet network test facilities
  - https://www.jisc.ac.uk/guides/using-the-janet-network-performance-test-facilities
  - Includes 10G and 100G perfSONAR servers
  - Raul has been testing 5.1 beta, and has some nice Grafana views!

- Research Network Engineering community:
  - https://www.jisc.ac.uk/get-involved/research-network-engineering-rne-community-group
  - Includes a BBR presentation in the archive
  - Next call is on perfSONAR 5.1
  - JiscMail list – *rne@jiscmail.ac.uk* - join at https://www.jiscmail.ac.uk/RNE

Some examples

Configuring servers for tests

Must ensure pscheduler can use a full range of parameters

- Server set open for 3rd party testing
- BBRv3 installed (not necessarily as the default CCA)
- 9000 MTU enabled
- IPv6 enabled
- Enhanced window/buffer size settings by default (e.g., using settings from FasterData)

Example: cubic vs BBR

CUBIC

```
$ pscheduler task throughput  --source ps-london-bw.perf.ja.net --dest a.n.other.perfsonar --congestion cubic

* Stream ID 5

Interval       Throughput     Retransmits    Current Window
0.0 - 1.0      5.10 Gbps      3852           13.24 MBytes
1.0 - 2.0      5.51 Gbps      0              13.66 MBytes
2.0 - 3.0      5.66 Gbps      0              14.03 MBytes
3.0 - 4.0      5.82 Gbps      0              14.35 MBytes
4.0 - 5.0      5.89 Gbps      0              14.63 MBytes
5.0 - 6.0      6.01 Gbps      0              14.86 MBytes
6.0 - 7.0      6.12 Gbps      0              15.06 MBytes
7.0 - 8.0      6.16 Gbps      0              15.22 MBytes
8.0 - 9.0      6.20 Gbps      0              15.35 MBytes
9.0 - 10.0     6.30 Gbps      0              15.45 MBytes

Summary
Interval       Throughput     Retransmits    Receiver Throughput
0.0 - 10.0     5.88 Gbps      3852           5.80 Gbps
```

Example: cubic vs BBR

BBR

```
$ pscheduler task throughput  --source ps-london-bw.perf.ja.net --dest a.n.other.perfsonar --congestion bbr

* Stream ID 5

Interval      Throughput     Retransmits    Current Window
0.0 - 1.0     13.51 Gbps     113552         44.39 MBytes
1.0 - 2.0     18.54 Gbps     40645          113.13 MBytes
2.0 - 3.0     18.65 Gbps     37872          116.69 MBytes
3.0 - 4.0     19.29 Gbps     15092          104.01 MBytes
4.0 - 5.0     18.17 Gbps     8263           102.90 MBytes
5.0 - 6.0     15.82 Gbps     5605           103.43 MBytes
6.0 - 7.0     17.86 Gbps     52285          110.02 MBytes
7.0 - 8.0     19.10 Gbps     31216          112.44 MBytes
8.0 - 9.0     16.70 Gbps     73078          98.93 MBytes
9.0 - 10.0    18.71 Gbps     77432          114.61 MBytes

Summary
Interval      Throughput     Retransmits    Receiver Throughput
0.0 - 10.0    17.63 Gbps     455040         17.40 Gbps
```

Note: the retransmissions
are **much** greater with BBR

The destination has been
anonymised given there is
some packet loss

Also note that BBR is only
Required sender side, but other
Network configuration will matter

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Example: cubic vs BBR (CERN – Janet)

CUBIC

```
$ pscheduler task throughput  --source pse01-gva.cern.ch --dest ps-london-bw.perf.ja.net --congestion cubic

* Stream ID 5
Interval       Throughput     Retransmits    Current Window
0.0 - 1.0      451.29 Mbps    0              2.85 MBytes
1.0 - 2.0      5.89 Gbps      503            17.73 MBytes
2.0 - 3.0      8.79 Gbps      0              18.64 MBytes
3.0 - 4.0      8.67 Gbps      0              19.47 MBytes
4.0 - 5.0      9.46 Gbps      0              20.23 MBytes
5.0 - 6.0      9.37 Gbps      0              20.91 MBytes
6.0 - 7.0      9.46 Gbps      0              21.53 MBytes
7.0 - 8.0      9.81 Gbps      0              21.92 MBytes
8.0 - 9.0      10.41 Gbps     0              22.57 MBytes
9.0 - 10.0     9.96 Gbps      0              23.02 MBytes

Summary
Interval       Throughput     Retransmits    Receiver Throughput
0.0 - 10.0     8.23 Gbps      503            8.21 Gbps
```

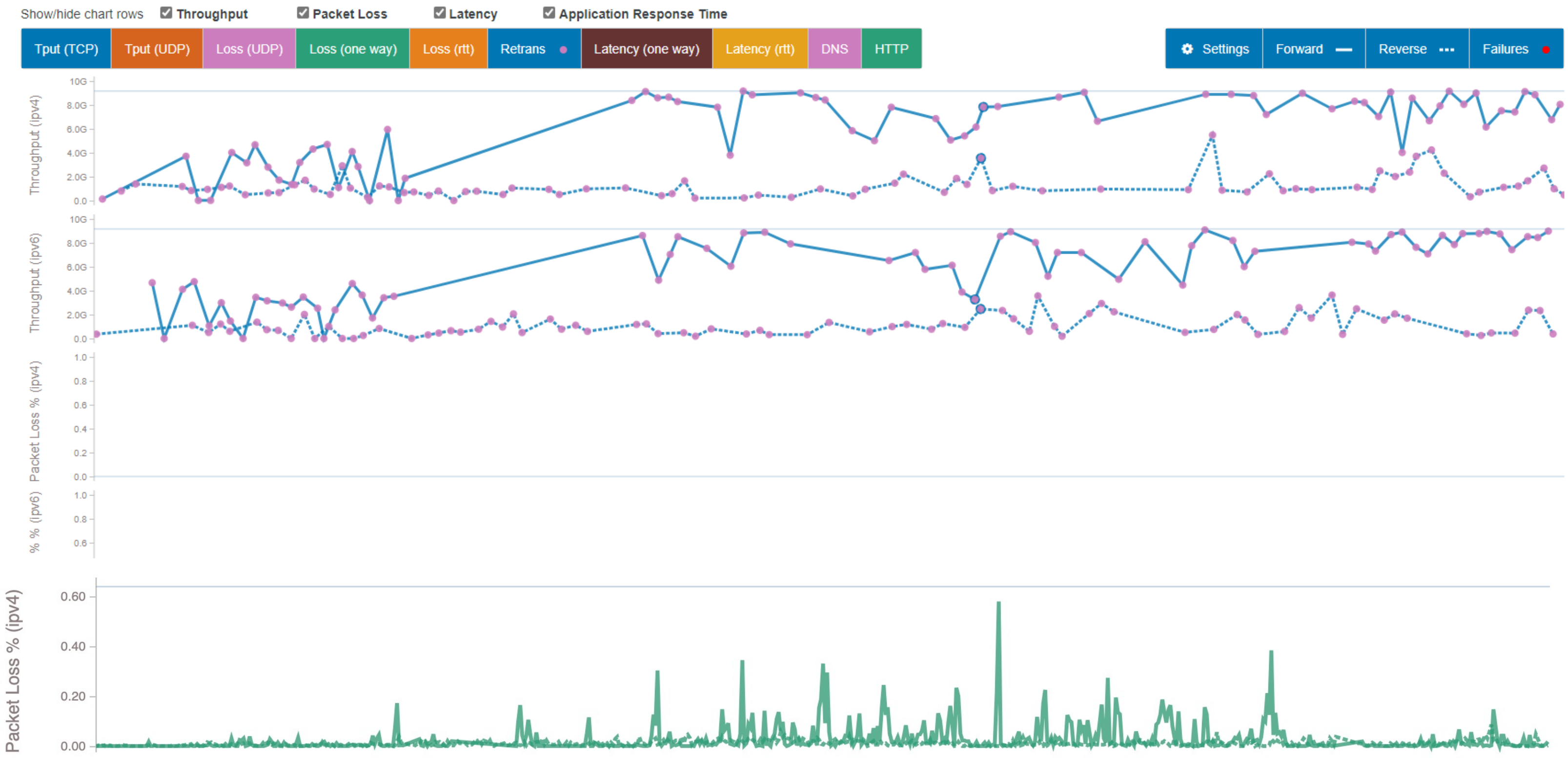
Example: cubic vs BBR (CERN – Janet)

BBR

```
$ pscheduler task throughput  --source pse01-gva.cern.ch --dest ps-london-bw.perf.ja.net --congestion bbr

* Stream ID 5

Interval        Throughput      Retransmits     Current Window
0.0 - 1.0       9.04 Gbps       26866           74.03 MBytes
1.0 - 2.0       12.81 Gbps      0               59.20 MBytes
2.0 - 3.0       10.84 Gbps      349             58.23 MBytes
3.0 - 4.0       11.73 Gbps      19408           63.83 MBytes
4.0 - 5.0       12.73 Gbps      1140            54.63 MBytes
5.0 - 6.0       10.35 Gbps      10339           52.01 MBytes
6.0 - 7.0       12.55 Gbps      0               49.73 MBytes
7.0 - 8.0       12.46 Gbps      0               49.56 MBytes
8.0 - 9.0       12.58 Gbps      0               50.88 MBytes
9.0 - 10.0      12.49 Gbps      0               49.69 MBytes

Summary
Interval        Throughput      Retransmits     Receiver Throughput
0.0 - 10.0      11.76 Gbps      58102           11.74 Gbps
```

In this case the path from CERN to Janet is a good, relatively short and loss-free one, so there is less benefit from BBR in terms of the throughput achieved

US-UK example: BBR improvement (lossy destination)



Thoughts

What might we do?

What could we add to perfSONAR to support this use case?

- perfSONAR commonly used to measure network characteristics over time
- The capability for perfSONAR to test network configuration changes, and new tools such as BBR, is often overlooked
- WLCG Data Challenge 24 illustrated the power of *pscheduler*
- Need to ensure open nodes are available
- **How might we best schedule comparative tests?**
- **How can we make useful visualisations for comparitive measurements?**
- A lot of potential here!

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